

CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, coffee is one of the most popular commodities in the developed world. Supermarkets and coffee shops are always stocked with a plenty supply of coffee blends and flavors. In the past, the fresh coffee for home and catering brewing is available by the method of filtration (percolation), infusion or boiling (decoction) the roast and ground coffee (Clarke and Macrae, 1987). The process will normally take time with the requirement of some household or catering-type equipment. With the desire to make coffee instantly by simply mixing a dry or liquid concentrate with hot water, the product of soluble or instant coffee is marketed worldwide through the improvement of modern processing technology in food and beverage industry.

Instant or soluble coffee is a beverage that derived from brewed coffee beans. The coffee is dehydrated into the form of granules or powder through various manufacturing processes. It can be rehydrated using hot water to provide a drink similar to brewed coffee. Besides, the instant coffee is also available in the form of concentrated liquid. Instant coffee is manufactured from coffee beans through a series of process, including roasting, grinding, extraction, concentration, drying and

packing (Clarke and Macrae, 1987). It is normally to produce a soluble powder or granules, either by spray-drying or freeze-drying technique.

In recent years, the growth of the instant coffee market due to the modern consumer's desire for a convenience product has been impressive. Consequently, the market expansion has led to the production of increasing quantities of wastewater with high pollution potential and the spent coffee grounds as an unwanted by-product of instant coffee manufacture (Clarke and Macrae, 1987). Many research studies have been conducted for the treatment, reusing and recycling of spent coffee grounds but there is lack of the focus on the instant coffee processing wastewater. The wastewater of instant coffee industry is primarily generated from cleaning operations including equipment cleaning and floor washing. It is important to treat the instant coffee wastewater with proper, effective and economical practices prior to their discharge into the receiving water.

1.2 Research Background

The first soluble instant coffee was invented by Dr. Satori Kato, a Japanese chemist in Chicago, and the soluble coffee was first sold to the public at the Pan-America Exposition of 1901 (Wrigley, 1988). Shortly thereafter, George Washington developed his own instant coffee process and it was first appeared on the American market in 1910 (Ukers, 1935). The Nescafé brand that introduced a more advanced coffee refining process was launched in 1938 (Clarke and Macrae, 1985). On a global basis, it is estimated that in 1980 about 19% of coffee consumed went into soluble manufacture and today the countries with the highest total consumption of instant coffee are, in order, United States of America (USA), United of Kingdom (UK), Japan, France, Germany and Canada (Clarke and Macrae, 1985). Now, the instant coffee can be found all over the world and it has been widely used for decades.

Instant coffee comes in three forms: freeze-dried, spray-dried and liquid coffee extract. A good cup of coffee can be made from the instant coffee with a number of advantages over fresh brewed coffee. The instant coffee allows the consumer to make coffee in an ease and convenience way without any equipment other than a cup and without having to discard any damp grounds. The preparation of coffee is simple and fast as no time is required for infusing the coffee and it is ready as soon as the hot water is added. The quality of instant coffee also has grown dramatically over the years. It stays fresher longer and has long shelf life because natural coffee, especially in ground form, loses flavor as its essential oils evaporate over time. In short, the instant coffee is fast, cheap and clean.

Instant coffee has become a product that attracts great attention in the food and beverage industries of Malaysia. Although Malaysia is not the major country of coffee plantation and green coffee production, there are more than thirty soluble and instant coffee manufacturers all around the country. The high technologies are used to manufacture regular and agglomerated instant coffee in the form of powder or granules as well as canned liquid coffee. The rapid growth of instant coffee industry is accompanied by a staggering increase in the amount of wastewater produced. The major sources of wastewater produced in the instant coffee processing industry include the water used for the cleaning of extractor, spray dryer, freeze concentrator, separator, heat exchanger, boiler, evaporator finisher and pasteurizer, washing the floors and working areas (Lim, 1999).

The International Coffee Organization (ICO) has proposed the Common Code for the Coffee Community (4C) to create a common global code to cover the economic, social, and environmental pillars for achieving greater sustainability of development for coffee industry (Osorio, 2005). From the aspect of environment that related to coffee processing, there are three main issues to be considered, which included proper wastewater treatment, utilizing by-products, and conserving energy. The water quality and aquatic ecosystem will be affected seriously if the high strength and polluted wastewater from coffee processing is discharging into the receiving water without any suitable treatment system.

Different products of instant coffee with different technology can lead to different amounts and quality of wastewater produced. The production of instant coffee gives rise to substantial volumes of wastewaters containing a wide variety of pollutants. In general, the wastewaters contain higher value of biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid (TSS) and turbidity. The wastewaters also possess a distinctive dark brown color. The pH can be in a wide range depending of its sources. Coffee wastewater contains high organic loads which may result in dissolved oxygen depletion in the receiving waters (Ricardo, 1996). The volume, concentration and composition of the effluent arising in the manufacturing plant are dependent on the type of product being processed, the production program, operating methods, design of the processing plant, the design of water management being applied, and subsequently the amount of water being conserved (Lawrence *et al.*, 2004).

For instant coffee industry, the wastewater is normally treated by physical and chemical, biological processes. The pretreatment or primary treatment is a series of physical and chemical operations, which precondition the wastewater as well as remove some of the wastes. The treatment is normally arranged in the sequence of screening, flow equalization, coagulation-flocculation, sedimentation, and dissolved air flotation (Lawrence *et al.*, 2004). Screening is applied to remove coarse particles in the influent while flow equalization is a method used to overcome the operational problems caused by flowrate variations. Coagulation is used to destabilize the stable suspended solids and colloidal particles while flocculation is used to aggregate the destabilized particles to form a larger and rapid-settling floc. This normally acts as preconditioning process for sedimentation and / or dissolved air flotation.

Biological processes have been developed for secondary treatment system to remove the dissolved and particulate biodegradable components in the wastewater (Metcalf and Eddy, 2003). Microorganisms are used to decompose the organic wastes. With regard to different growth types, biological systems can be classified as suspended growth or attached growth system. Furthermore, it can also be classified by oxygen utilization: aerobic, anaerobic and facultative. A research study of

anaerobic treatment by upflow anaerobic sludge blanket (UASB) process was carried out by the Nestlé Foods Corporation Purchase, which has one of the largest freeze-dried coffee plant located in Freehold, New Jersey and generated approximately 760 m³/day of wastewater (Lanting *et al.*, 1988). They study the treatability of coffee wastewater by using four pilot systems under both mesophilic and thermophilic conditions. The COD removals were between 49 to 69%.

1.3 Problem Statements

There has been limited research on coagulation and flocculation process for the pretreatment of instant coffee wastewater as comparing with other food and beverage industries. Due to the high concentration of organic pollutants and suspended solids in wastewater of soluble coffee processing, its disposal without an appropriate treatment into the receiving water has become undesirable because it will be very dangerous for the water bodies and human health. The wastewater discharged from any industries in Malaysia must follow the stringent effluent standard of Environment Quality Act (EQA) 1974. Thus, a proper and effective treatment system is needed. The pretreatment systems such as coagulation and flocculation processes play a significant role for overall performance of the wastewater treatment plant. It is important in reducing most of the suspended solids and organic matter in the raw wastewater before entering into the secondary treatment system (Metcalf and Eddy, 2003).

The most widely used coagulants in wastewater treatment are inorganic metal salts, such as aluminum or iron salts. Aluminum sulfate and ferric chloride have been extensively used as a primary coagulant in wastewater treatment. This is due to their effectiveness, cheap, easy to handle and availability (Edzwald, 1993). However, its best performance and cost-effectiveness can only be achieved during the optimum conditions of coagulation and flocculation process. It is important not to overdose the

coagulants because a complete charge reversal and restabilization of colloid complex can be occurred.

Recently, there is more attention on the extensive use of aluminum-based coagulant. Besides producing large amount of sludge, the high level of aluminum residual in the treated water has raised concern on public health. McLachlan (1995) discovered that intake of large quantity of alum salt may cause Alzheimer disease. To minimize the detrimental effect accompanied with the use of alum, polymers are added either with alum or alone and have gradually gained popularity in water treatment process. Synthetic polyelectrolytes produce sludge of better dewatering characteristics with smaller volume and facilitate better filtration, but their long-term effects on human health are not well understood (Pan *et al.*, 1999). Furthermore, the sludge formed during flocculation with synthetic polymers has a limited potential for recycling due to the non-biodegradability of synthetic polymers (Bratskaya *et al.*, 2004).

Therefore, it is necessary to develop a more effective and environment friendly coagulant as a viable alternative to these chemical coagulants. Since most of the wastewater colloids are negatively charged, natural cationic polyelectrolytes, such as chitosan has become a particular interest. Besides promotes an excellent pollutant removal, the biodegradability and non-toxic nature of chitosan provides an opportunity for water recycling in the industry and sludge recovery in the production of fertilizers or additives for animal feeding mixture. However, chitosan is same as aluminum sulfate or ferric chloride that must be applied in the optimum coagulation and flocculation conditions for the best performance and cost-effectiveness.

1.4 Objectives

The objectives of this study are stated as below:

1. To investigate the efficiency of coagulation and flocculation processes as a pretreatment for coffee industrial wastewater by using different types of coagulants (aluminum sulfate, ferric chloride and chitosan).
2. To evaluate the performance of aluminum sulfate, ferric chloride and chitosan in the reduction of total suspended solids (TSS), turbidity, chemical oxygen demand (COD) and color.
3. To determine the optimum conditions for the coagulation and flocculation processes of abovementioned coagulants.

1.5 Scope of Works

The steps and scopes leading to the objectives were:

1. To study and to determine the characteristics of raw wastewater from instant coffee processing industry.
2. To investigate the optimum dosage of the selected coagulants in reducing the pollutant load.

3. To determine the optimum pH for the coagulation and flocculation processes.
4. To compare the treatment efficiency by using aluminum sulfate, ferric chloride and chitosan.

1.6 Contribution of Study

This research will contribute on providing the optimum conditions of coagulation and flocculation process for common coagulant such as aluminum sulfate and ferric chlorite, applying for instant coffee processing wastewater. The research also explores the potential of coagulation treatment system by using chitosan, a natural polyelectrolyte. The knowledge obtained from this research will allow more efficient, effective and economical design and operation of pretreatment process for instant coffee industrial wastewater by using coagulation and flocculation.